Aeolian sediment transport on a wet beach: Field observations from the swash zone

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Research Question: How does the saltation concentration profile and transport flux change over wet surfaces in a field environment?

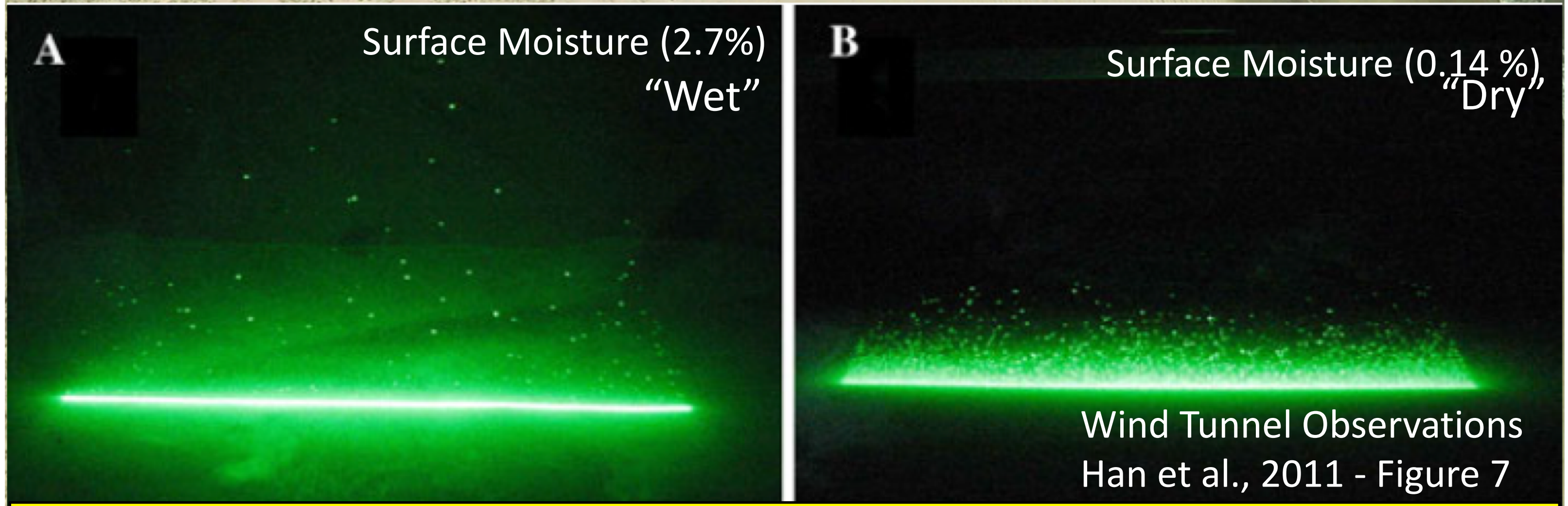
(1) Saltation height, speed & transport flux change with surface moisture content

[Svasek & Trewindt, 1974; Hotta et al. 1984; Sarre, 1988; van Dijk et al. 1996; McKenna-Neuman and Scott, 1998; Wiggs et al. 2004; Davidson-Arnott et al. 2005; Davidson-Arnott and Bauer, 2009; Delgado-Fernandez et al. 2011; Han et al., 2011; Nield and Wiggs, 2011; de Vries et al. 2014]

(2) Over wet surfaces, laboratory and field studies have found conflicting results

- Saltation height and/or total flux increases over a wet surface as particles retain more of their energy upon impact/rebound [van Dijk et al. 1996; McKenna-Neuman and Scott, 1998]
- Saltation flux increases ultimately from impact-driven transport – results in highly intermittent transport [Davidson-Arnott et al. 2005]
- Saltation flux decreases due to limited availability of sediment to move (too wet) – can also drive intermittency [Davidson-Arnott and Bauer, 2009; Delgado-Fernandez et al. 2011]
- Saltation flux decreases because saltators become trapped by wet surfaces [Han et al. 2011]
- Moisture content of 2% has little to no impact on transport flux [Wiggs et al. 2004]

Here, we aim to measure saltation concentration profiles & flux in the swash zone during a falling tide.



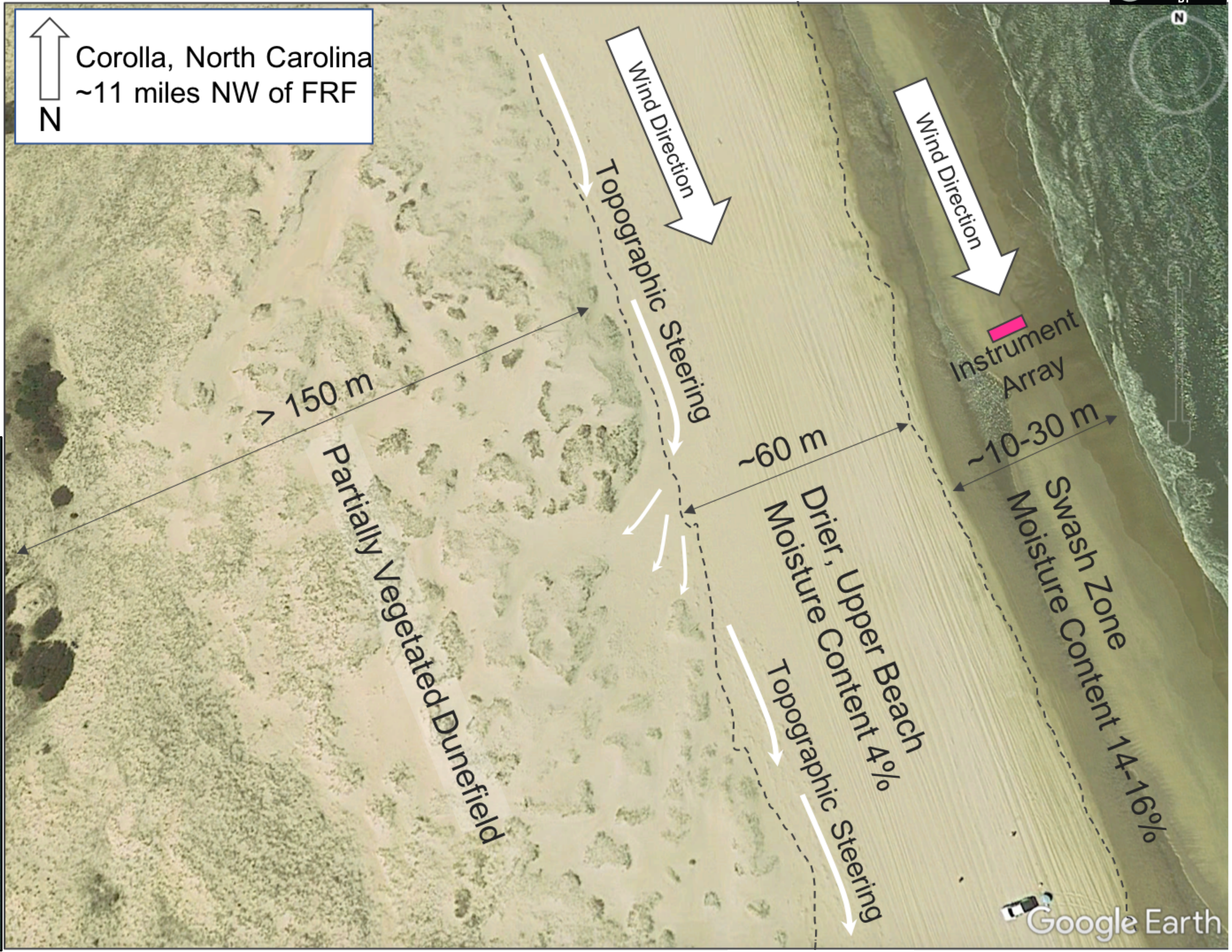
Wind Tunnel Observations
Han et al., 2011 - Figure 7

What will we see in the field?

Field Site

Corolla, North Carolina, USA

Beach Orientation: NNW – SSE
Beach Type: Dissipative
Grain Size: Very fine – medium size quartz sand (d = 0.17 mm)
Wind Direction: Aligned with beach orientation – unlimited fetch
Instrument Array: In the swash zone, very high moisture content

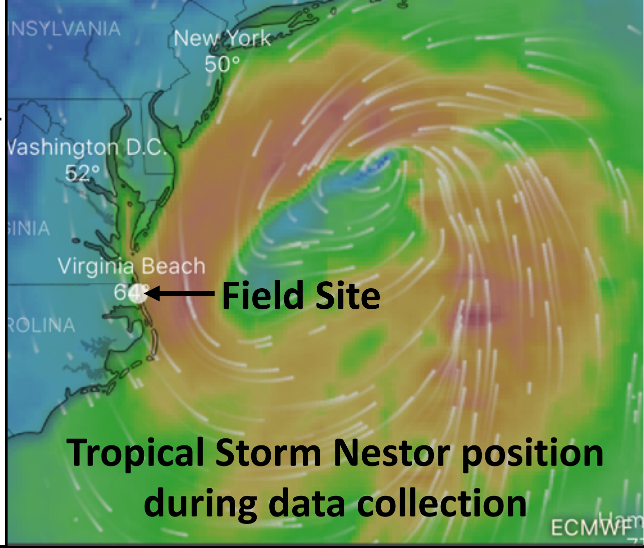


Field Observations

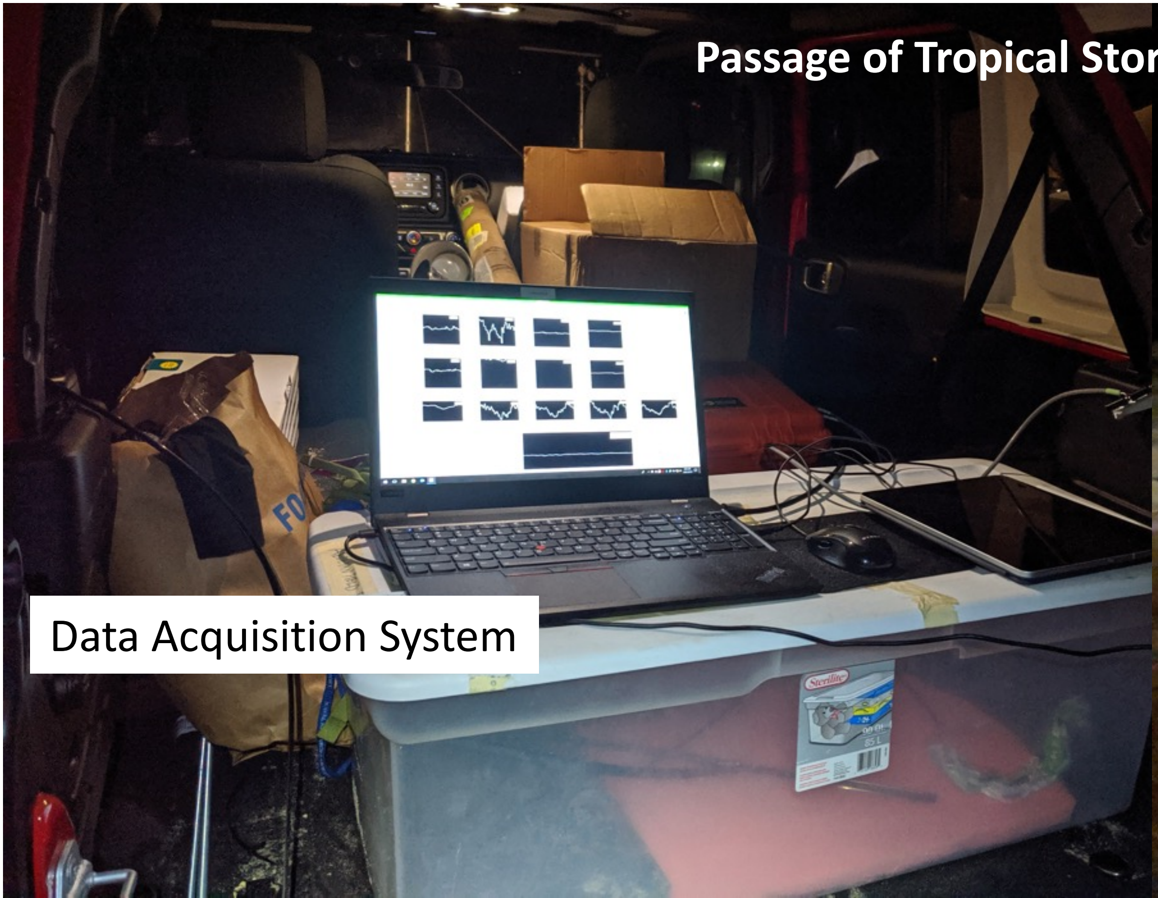
Wind Observations
- 3D Velocity Fluctuations via Sonic Anemometers
- Vertical Array of Cup Anemometers

Saltation Concentration Profiles
- Vertical Array of Saltation Traps

Gravimetric Moisture Content
- Surface Samples
  - Upper Beach
  - Swash Zone
- Vertical Array of Saltation Traps



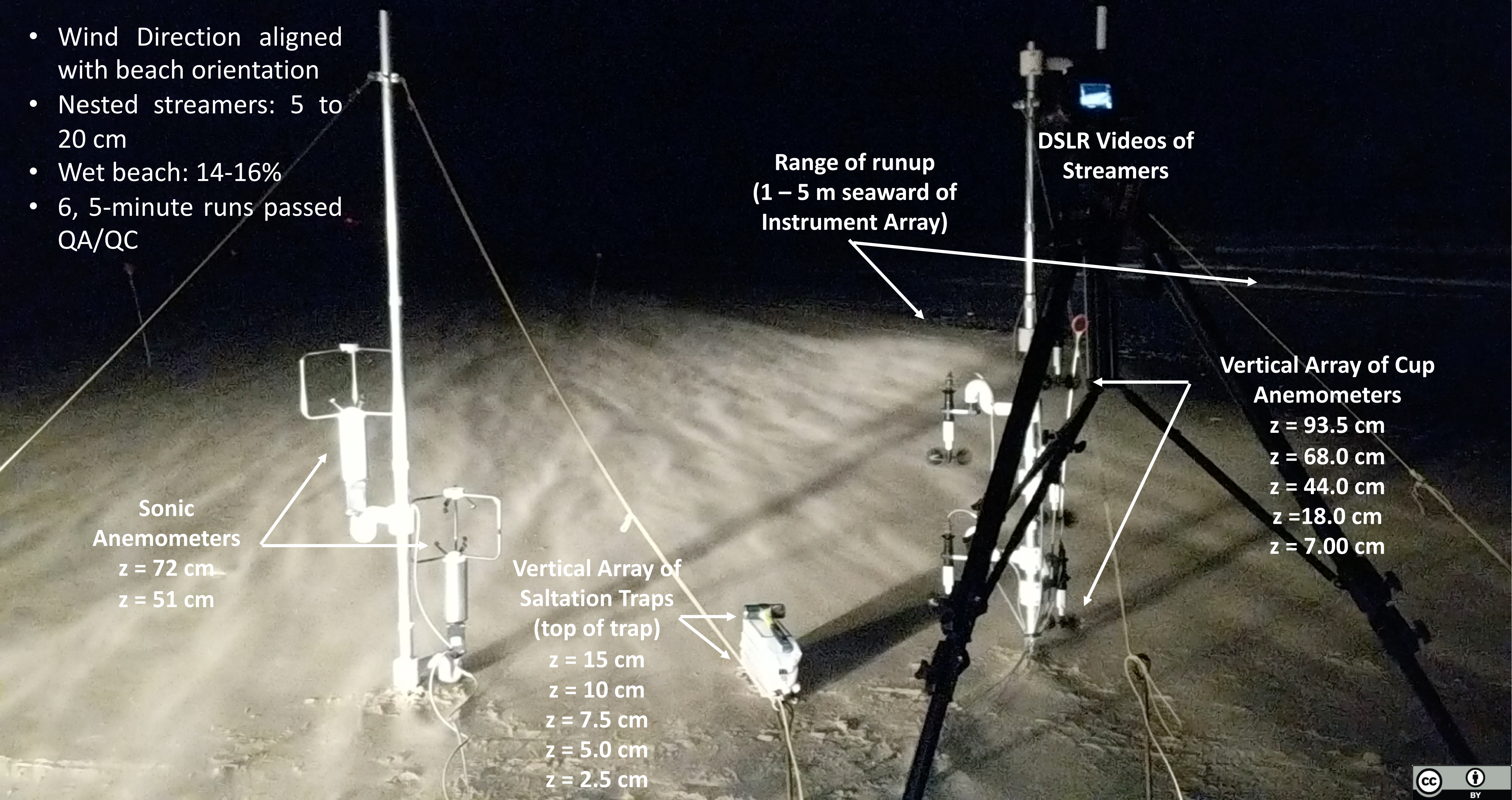
Passage of Tropical Storm Nestor (0600-0730 hours)



Field Observations

LINK TO VIDEO: https://drive.google.com/open?id=1JSvhteyCQssqevepGrnFrhVJ8BnN3Z2R

- Wind Direction aligned with beach orientation
- Nested streamers: 5 to 20 cm
- Wet beach: 14-16%
- 6, 5-minute runs passed QA/QC

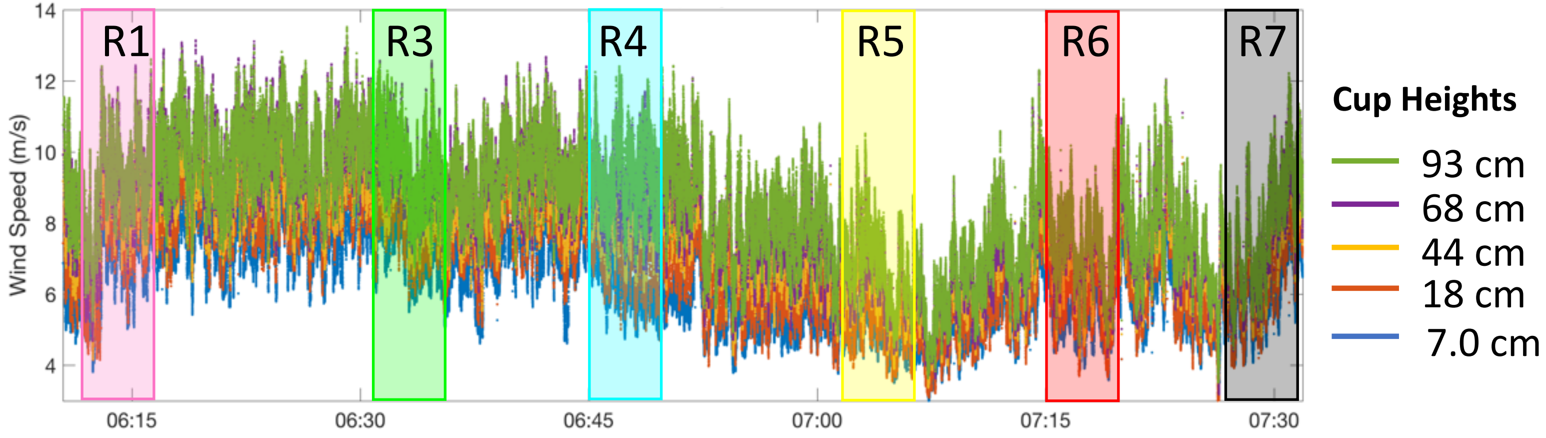


Cup Anemometer & Transport Data

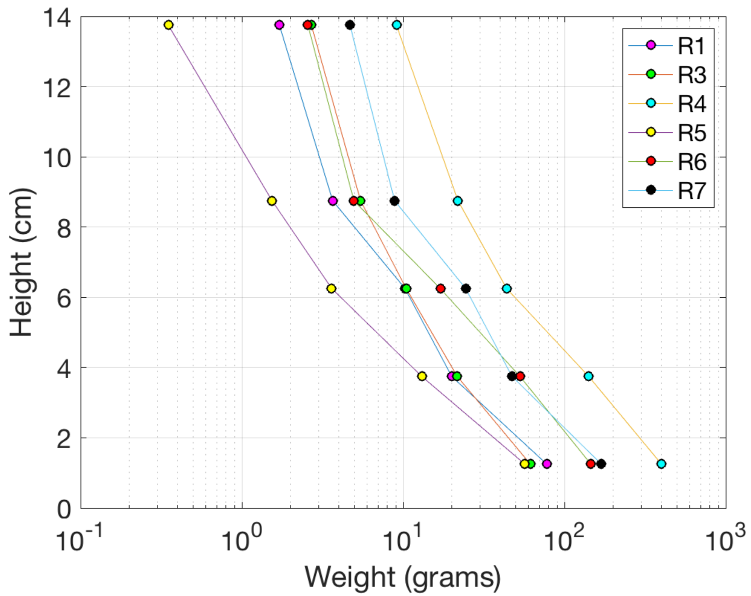
Strong winds & transport during the passage of Tropical Storm Nestor

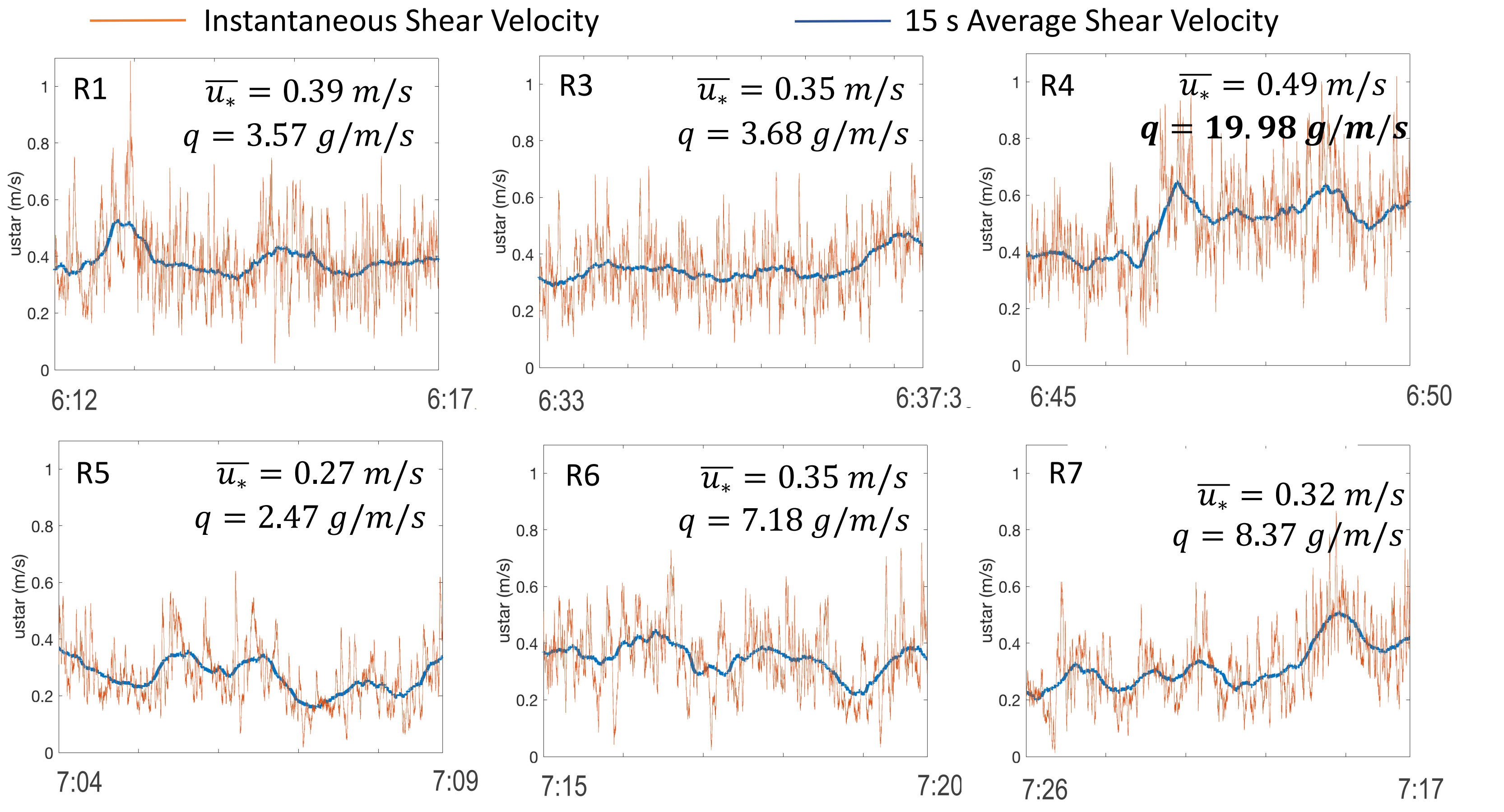
- R1, R3, R4: Sustained speeds @ 93 cm of 10 m/s
- R5: Slowest speeds
- 5-minute $\overline{u_*}$ ranged from 0.27 m/s (R5) to 0.49 m/s (R4)
- R4: Largest transport rate

Continuous Cup Anemometer Data



Sediment Trap Data



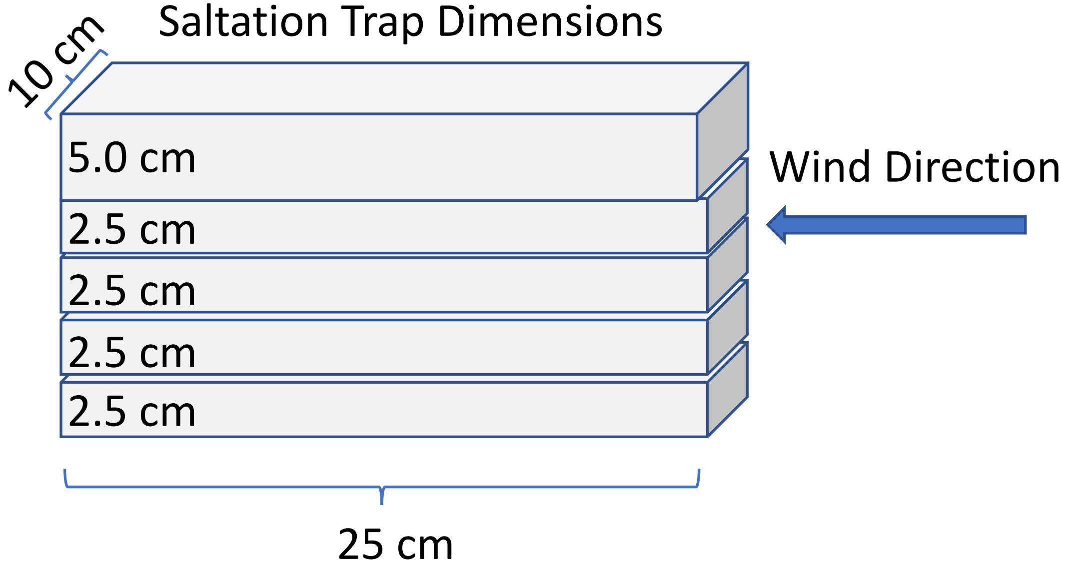


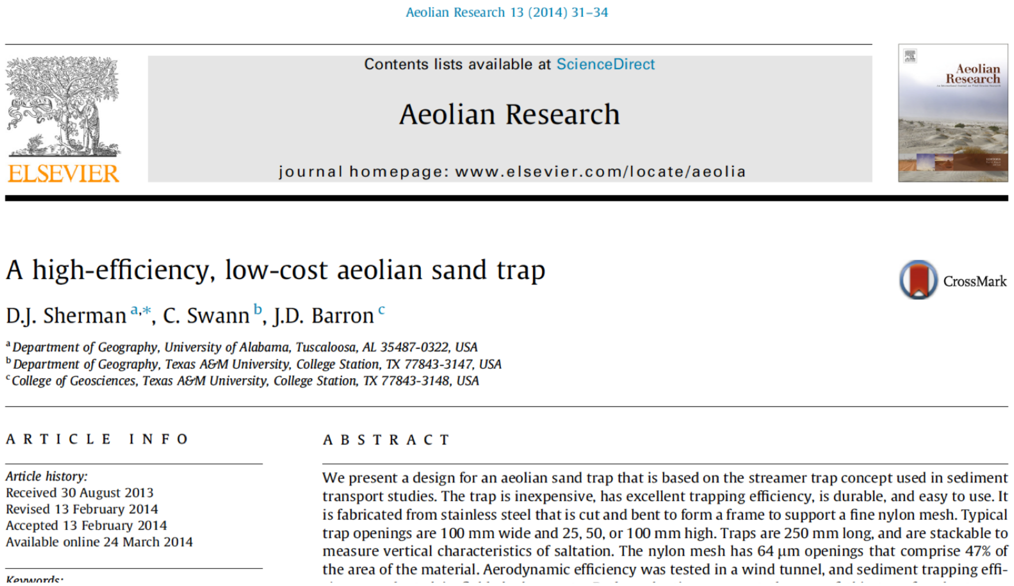
Saltation Trap Data

Grain size and moisture content acquired for each sample

- 35 samples from traps
- 3 grab samples for moisture content
- Removed Run 2 – sample collection failure in field (attributed to lack of coffee at 0600 hours)

Saltation Trap Dimensions

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A high-efficiency, low-cost aeolian sand trap

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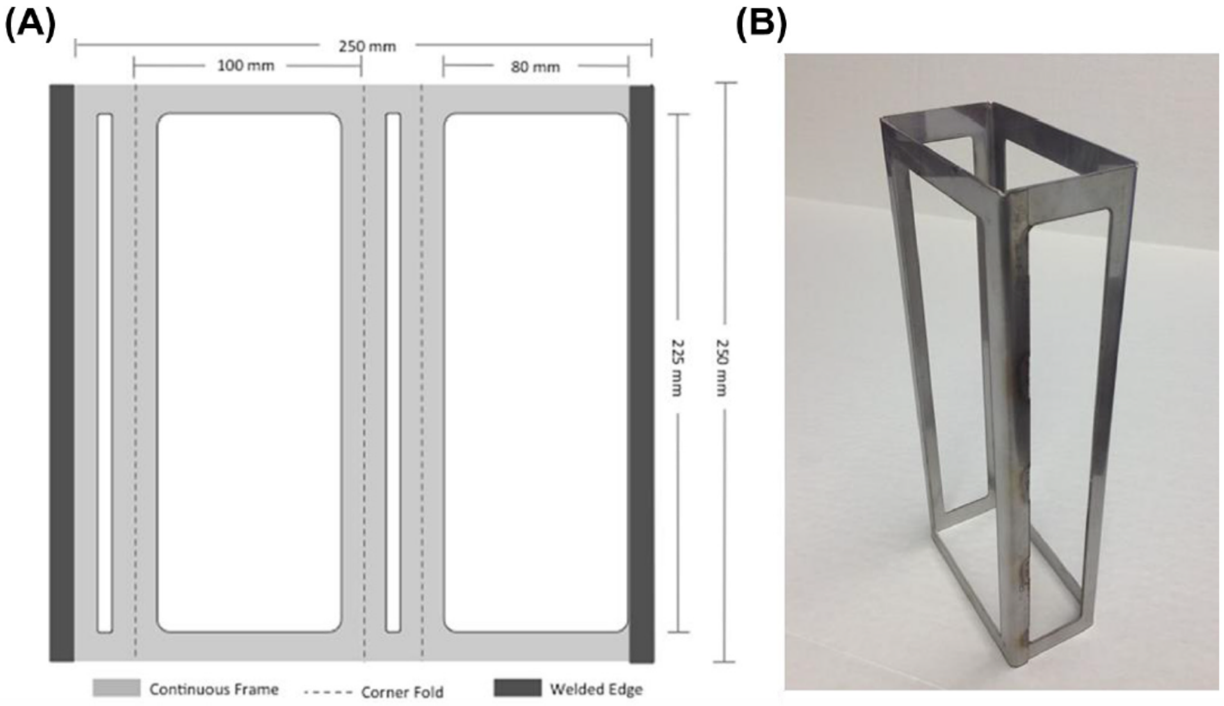
ABSTRACT

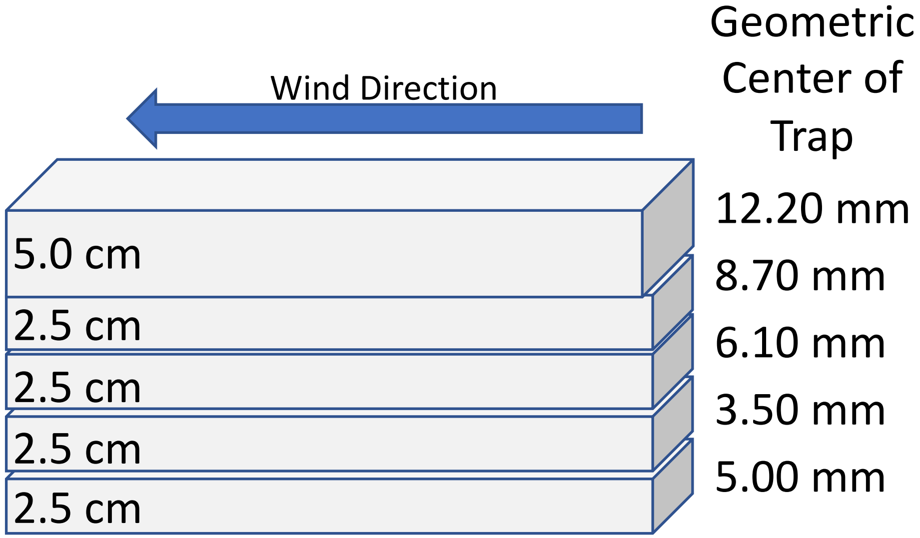
We present a design for an aeolian sand trap that is based on the streamer trap concept used in sediment transport studies. The trap is inexpensive, has excellent trapping efficiency, is durable, and easy to use. It is fabricated from stainless steel that is cut and bent to form a frame to support a fine nylon mesh. Typical trap openings are 100 mm wide and 25, 50, or 100 mm high. Traps are 250 mm long, and are stackable to measure vertical characteristics of saltation. The nylon mesh has 64 μm openings that comprise 47% of the area of the material. Aerodynamic efficiency was tested in a wind tunnel, and sediment trapping effi-

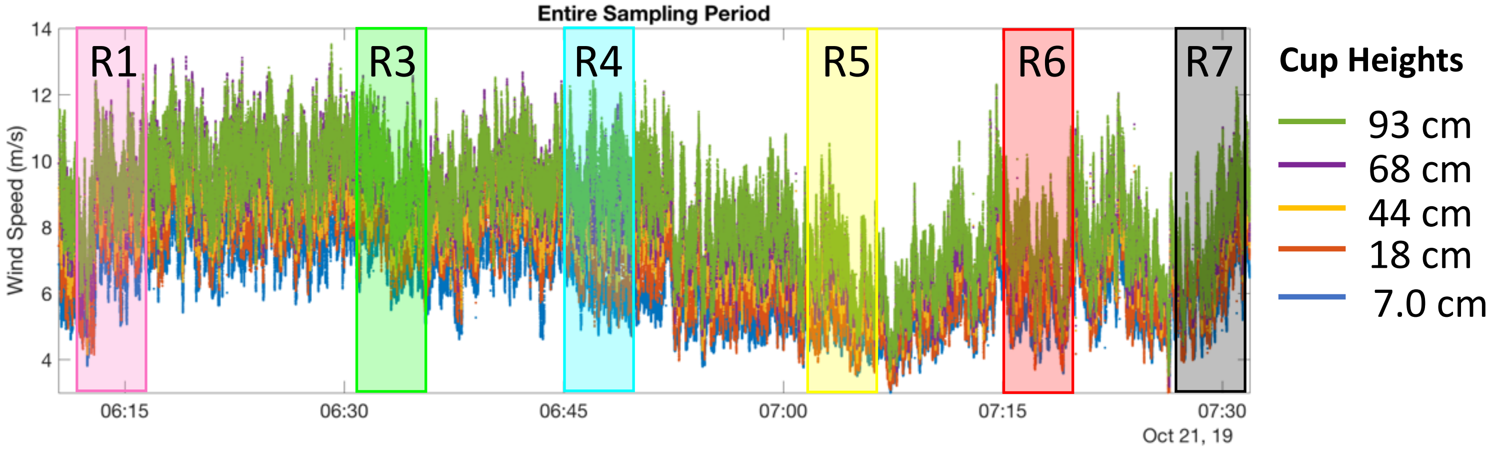


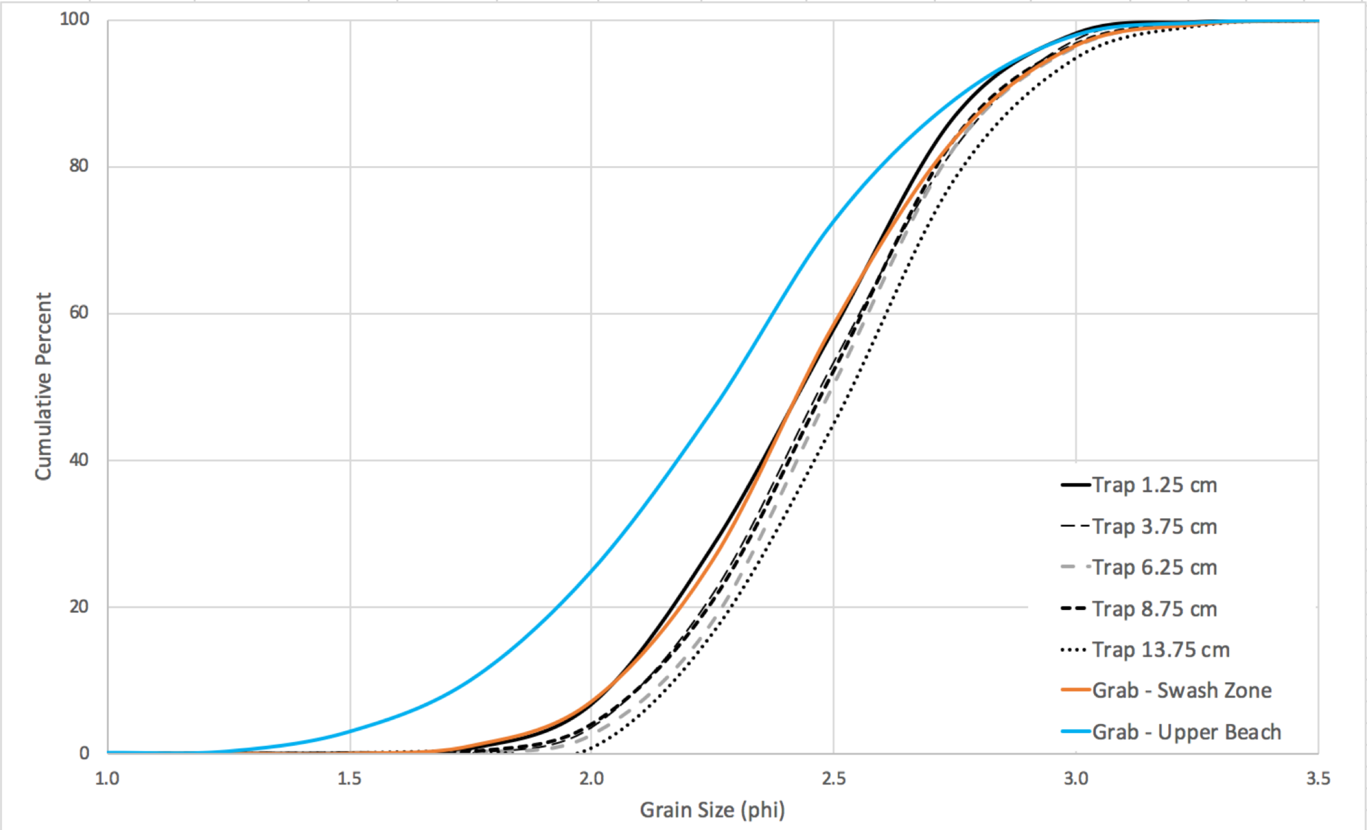
Saltation Trap Data

Grain population consistent between trap and swash zone grab samples

- Surface population and saltators have similar grain size distribution, with an slight increase in grain size with the highest trap
- Upper beach sediments coarser than saltators and swash zone sediments







Saltation Trap Data

Normalized Flux, Q_{ni}:

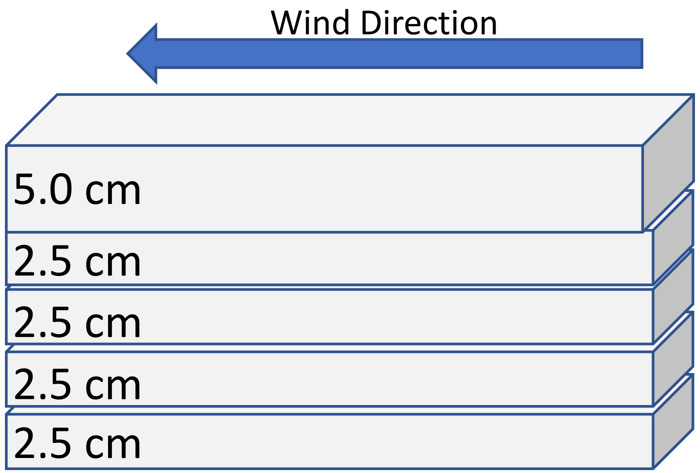
$$Q_{ni} = \frac{\dfrac{Q_i}{h_{ti} - h_{bi}}}{\sum_{i=1}^{5}(Qi)}$$

where,

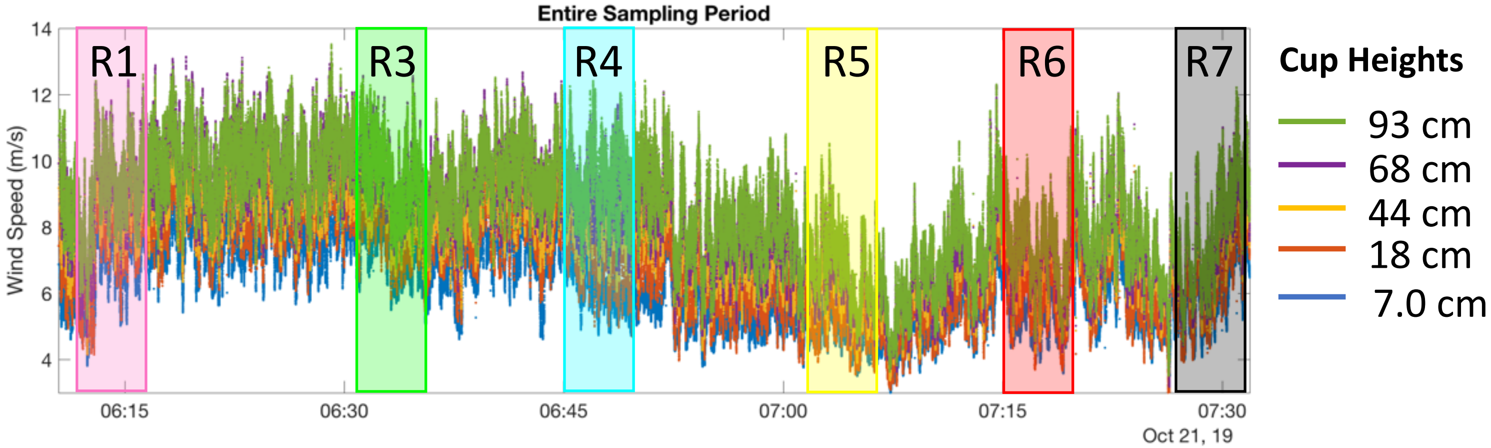
h_{ti} = z at the top of the trap

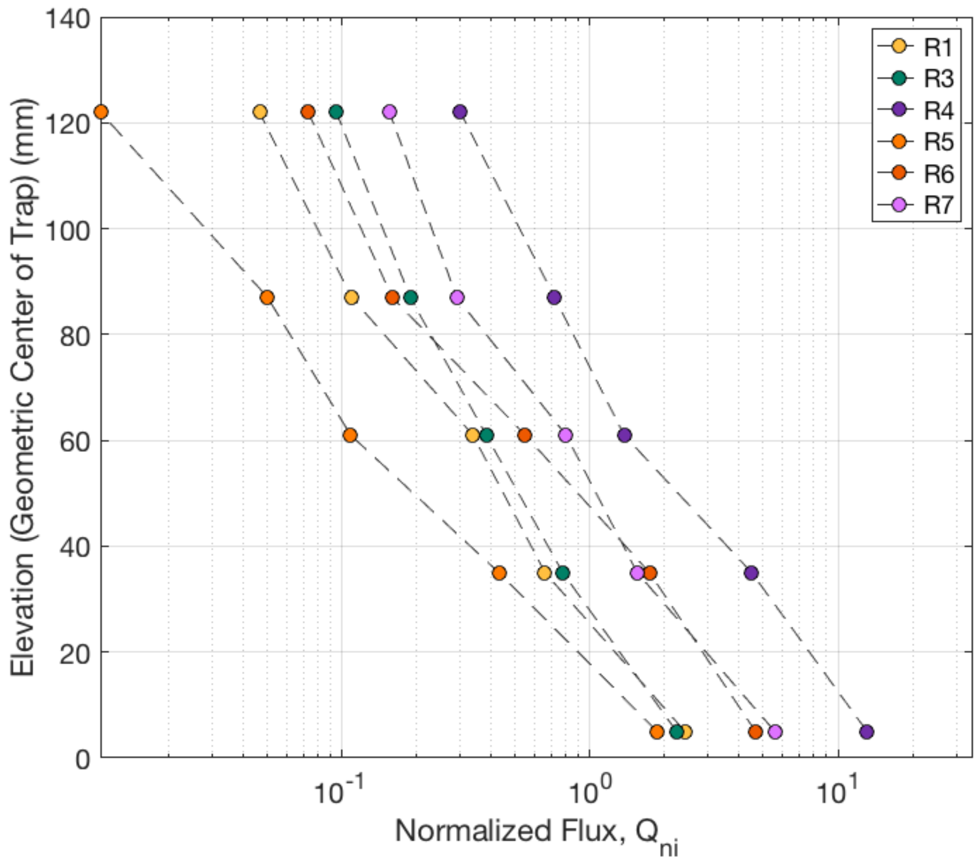
h_{bi} = z at the bottom of the trap

Q_i = flux in individual trap



Geometric Center of Trap
12.20 mm
8.70 mm
6.10 mm
3.50 mm
5.00 mm

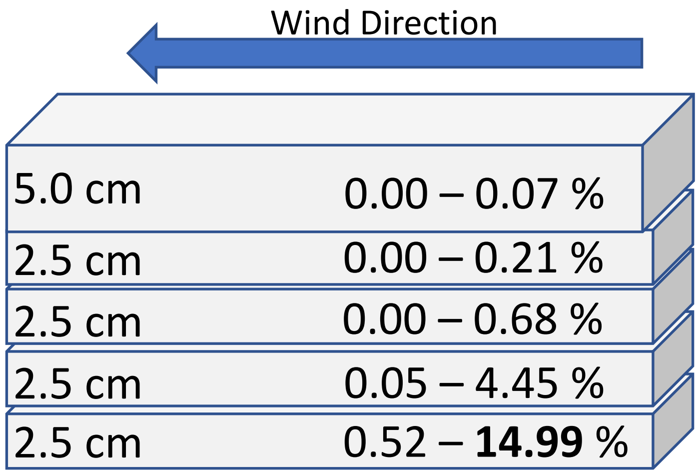


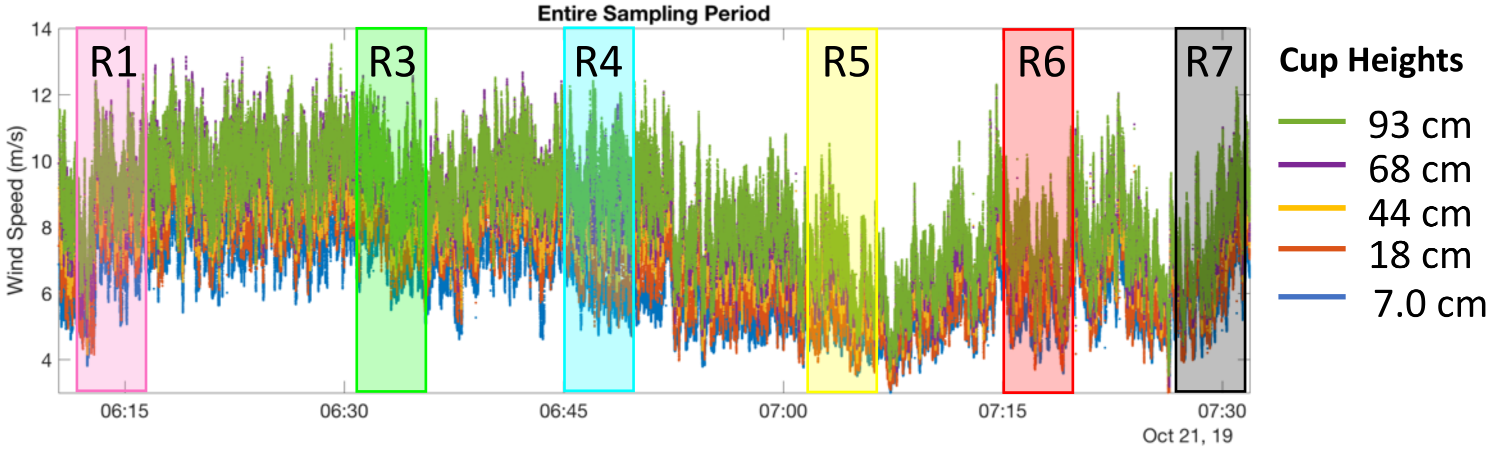


Saltation Trap Data

Moisture content varied with height

- Moisture content high in lowest traps (0 - 14.99%)
- Moisture content varied with each run
- Moisture content of surface samples are not correlated with increases in mean shear velocity
- Suggests dependency on impact-driven transport





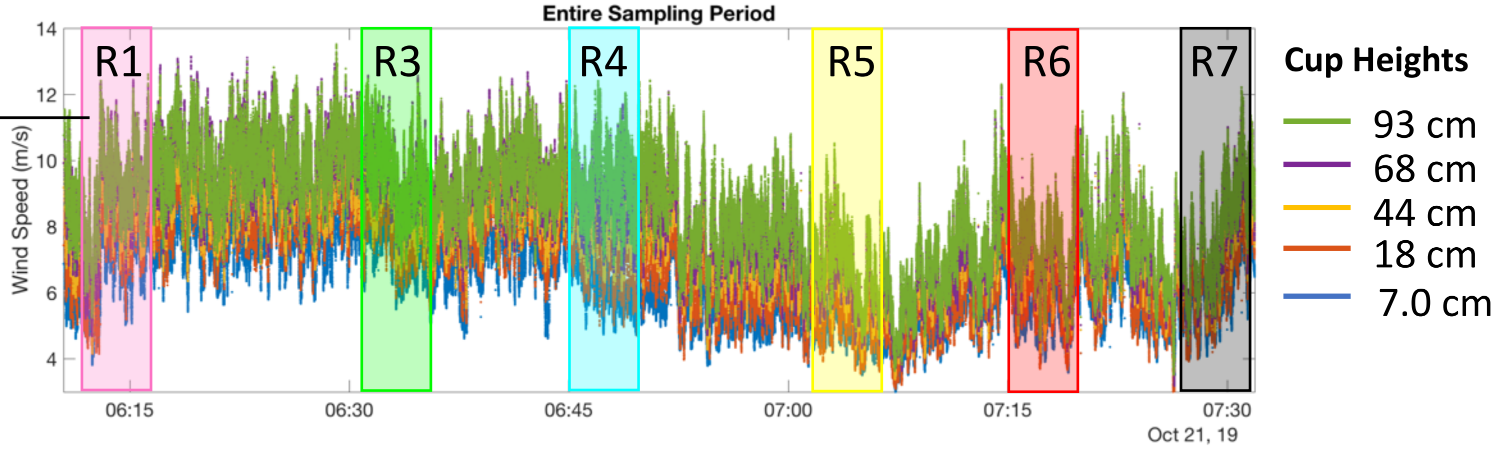
Gravimetric Moisture Content (%)

	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5
Top of Trap (m)	0.025	0.05	0.075	0.1	0.15
Geometric Center (m)	0.005	0.035	0.061	0.087	0.122
R1	6.52	0.21	0.07	0.03	0.07
R3	1.40	0.91	0.08	0.02	0.04
R4	14.99	4.45	0.00	0.21	0.04
R5	0.52	0.05	0.31	0.00	0.00
R6	4.04	0.86	0.09	0.02	0.05
R7	1.28	0.96	0.68	0.00	0.04

Error or real?

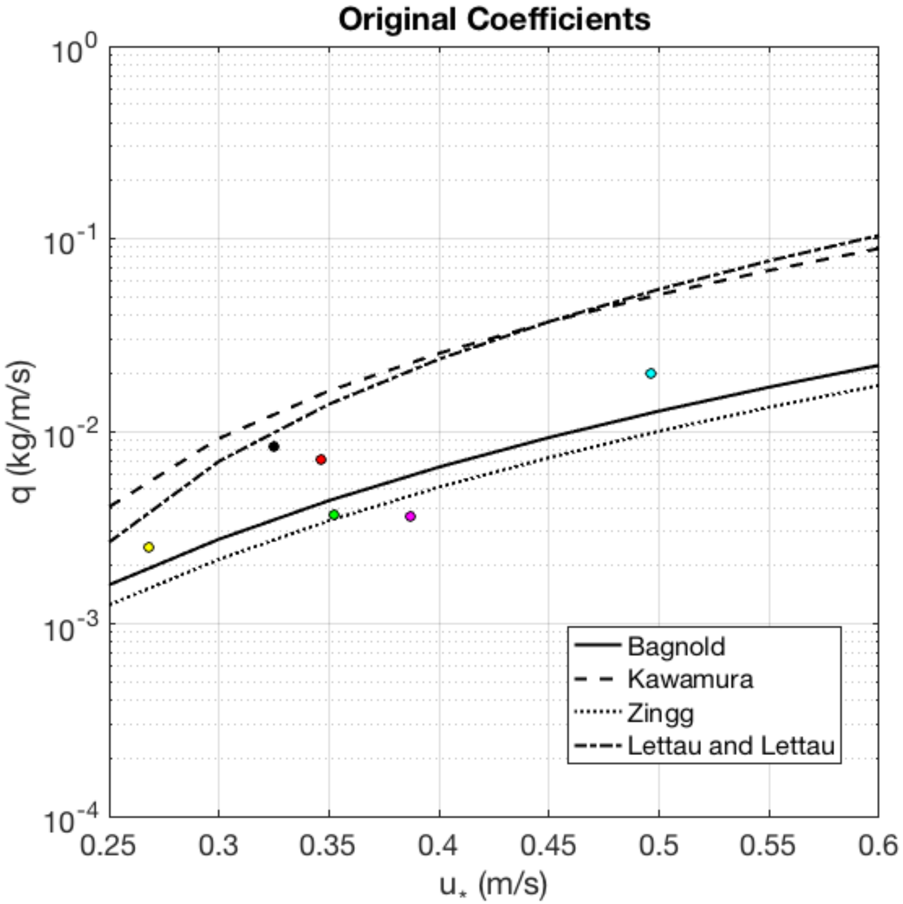
- **R4: 14.99% moisture consistent with surface moisture (14-16%)**
- Suggests the surface was active in the saltation process, i.e. the surface was not simply a passive surface that particles were transporting over, but actually mobile
- Surface eroded by 0.5 cm reduction in surface height (between 0600 and 0730 hours)

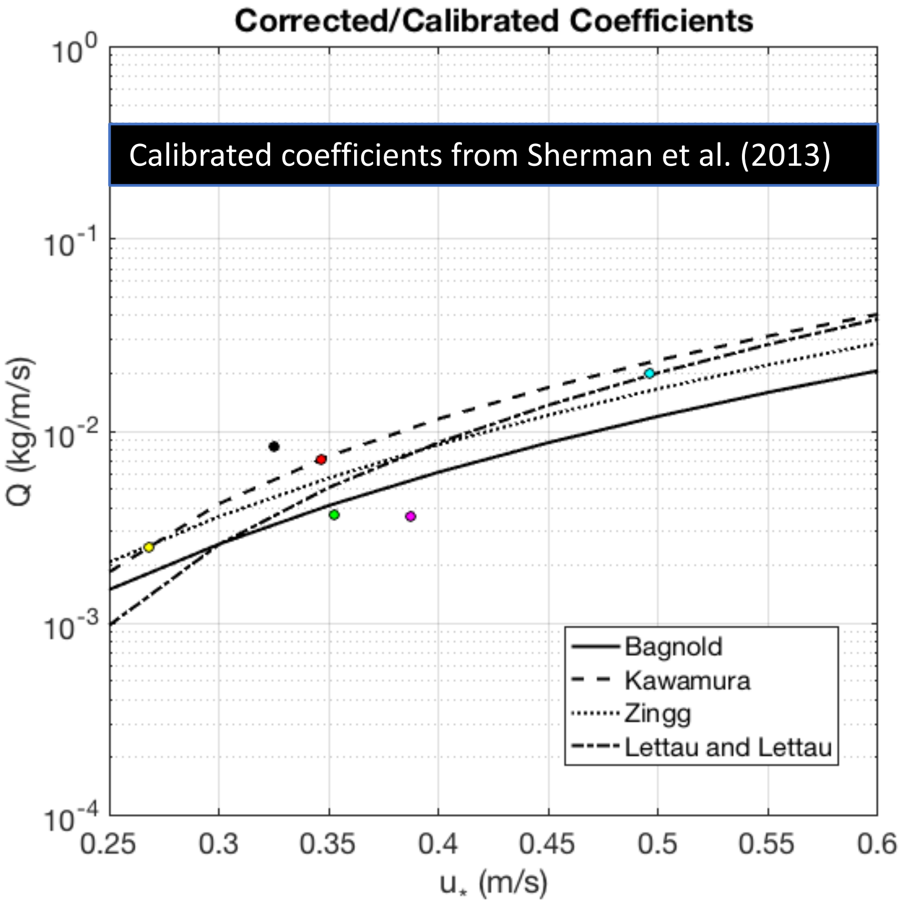
Model Comparison



Predicted vs observed transport rate

- Observations align well with calibrated coefficients
- Note log scale – so there is still some error in model prediction





Saltation Profile Comparison: Saltation profiles over **wet** vs **dry** surfaces

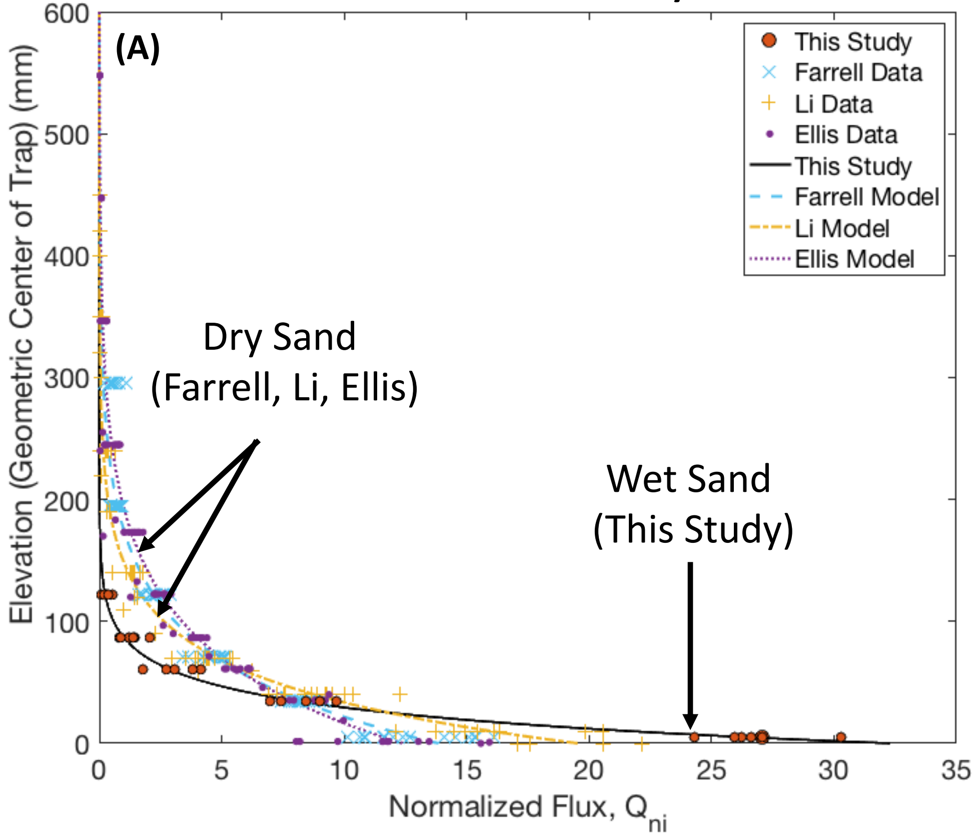
Saltation profile significantly different than for a dry surface

- **61 – 76%** of total transport occurs below 2.5 cm for the **wet** surface
- Transport over dry surfaces show much lower estimates

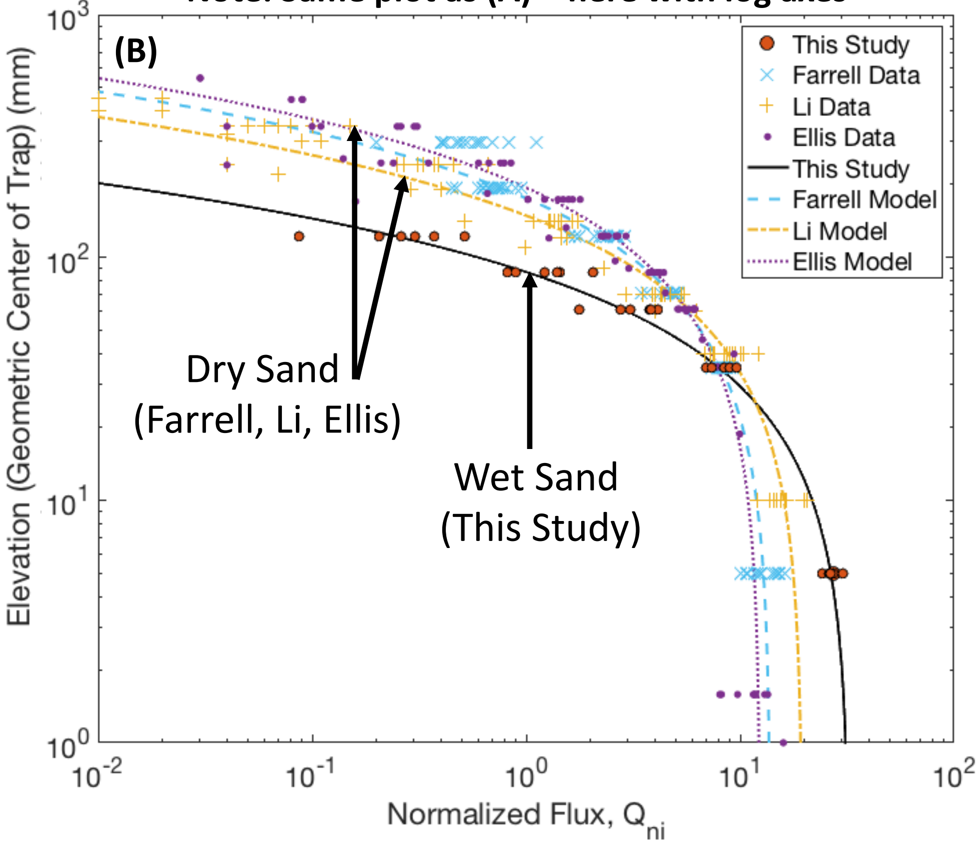
Percent of transport below 2.5 cm for **dry** surfaces:

- 32-36% Ellis et al. (2009)
- 37-52% for Farrell et al. (2012)
- 42-63% for Li et al. (2009)
- (note percentages are calculated from normalized flux)

Note: Elevation is on the y axis



Note: Same plot as (A) – here with log axes



Saltation Profile Comparison: Saltation profiles over **wet** vs **dry** surfaces

Comparison to saltation profiles over dry surfaces reveals more transport a lower heights

- Saltation profiles follow an exponential function (Ellis et al. 2009)

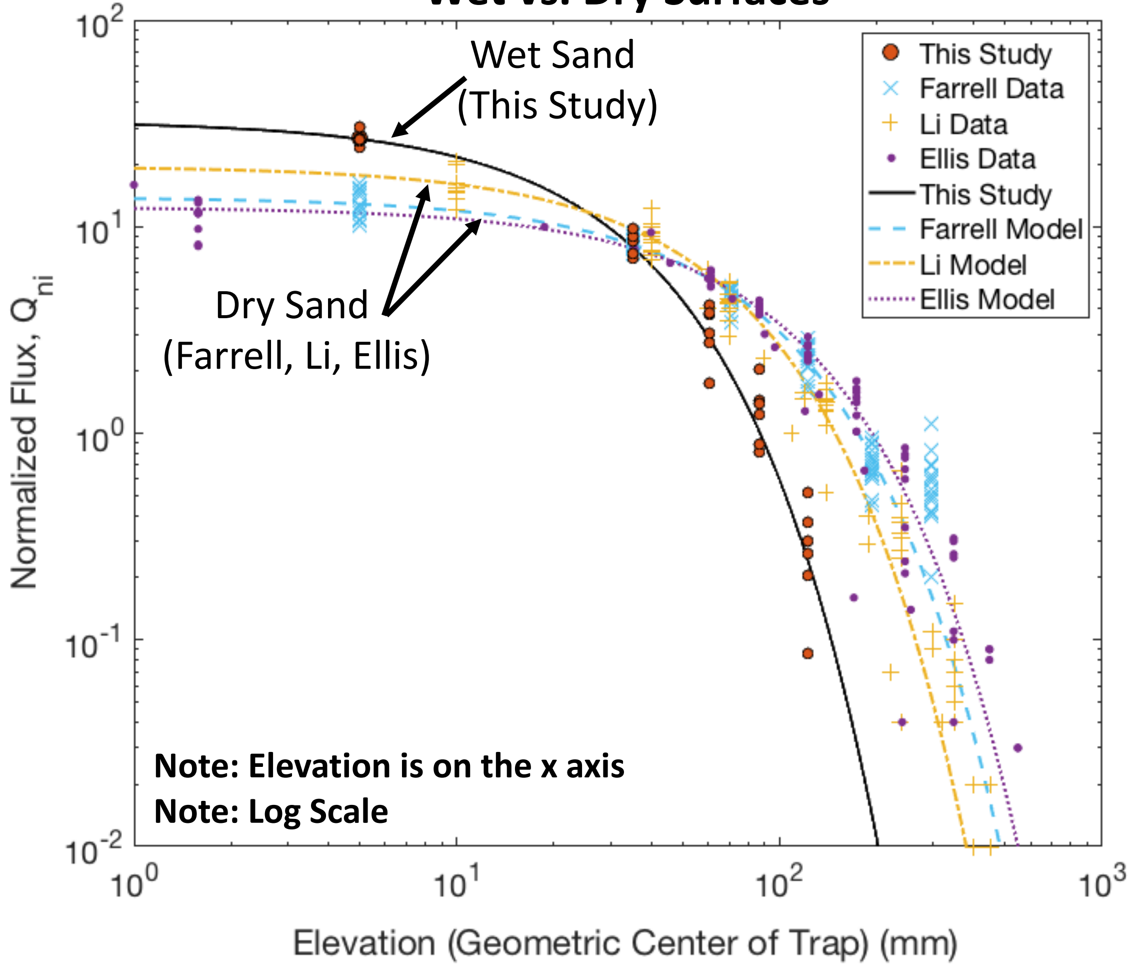
$$Q_{ni} = \alpha e^{\beta h}$$

Empirical Coefficients for Exponentional Expression of Saltation Flux

	d (mm)	α	β	R^2	Site Characteristics
Ellis et al. (2009) modified: Dry Sand	0.39	12.41	-0.013	0.93	Flat, sand sheet
Farrell et al. (2012): Dry Sand	0.26-0.35	13.86	-0.015	0.96	Dry rippled surface
Li et al. (2009): Dry Sand	0.27 - 0.35	19.57	-0.02	0.96	Near top of large parabolic
This Study: Wet Sand (14-16%)	0.17	32.41	-0.04	0.99	In swash zone

- Larger portion of flux occurring below 2.5 cm over wet surface
- Possibly due to smaller grain size of particles in this study (see Table)
- Possibly due to wet particles in motion having more mass from absorbed water/films – thus, saltation trajectories are altered

Field-derived saltation profiles Wet vs. Dry Surfaces



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